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A WATER POLLUTION SURVEY

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A Water Pollution Survey

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The reactions of pollution in a stream are highly complex and variable. The characteristics of the wastes and the manner in which they are discharged exert important influences on the resulting reactions. They are affected by volume and velocity of flow in the stream, chemical content, and the temperature and clarity of the flowing water. Physical characteristics of the stream channel, including slope, composition and irregularities of the bed, changes in direction, and size and shapes of representative cross sections are important factors. Weather conditions, including temperature, sunshine, clouds, precipitation and wind, affect the reactions. Finally, the infinitely complex biological, including bacterial, population of the water is the ever changing key to the reactions which accomplish natural purification of organic wastes.

When it is realized that conditions in a polluted stream can change not only from day to day but actually from hour to hour, it becomes obvious that a great deal of thought in planning, and care and effort in execution are essential to accomplish a successful stream pollution survey. If these two phases are not performed properly the needed answers will not be forthcoming regardless of the statistical manipulations that may be applied to interpretation of the data.

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PLANNING THE SURVEY

OBJECTIVES

The first step in planning the pollution survey is to define clearly the reasons for the survey and the problems that must be resolved. Detailed objectives will vary with the individual situation involved but the general objectives of most water pollution surveys are:

1. Determination of existing water quality as affected by pollution.
2. Extrapolation of the results of the survey to define conditions that may be anticipated under more adverse circumstances which can occur.
3. Evaluation of existing and potential effects of pollution on water uses.
4. Determination of any changes in waste discharges needed to assure reasonable protection of existing and potential water uses.

The general objectives must be reduced to specific objectives in an individual situation through consideration of all facets of the individual problem. The almost endless combinations of circumstances that may be encountered in actual practice make it pointless to illustrate here the specific objectives that would apply in a single situation. The general objectives may be narrowed somewhat, however, if only one of the nine major uses of water be considered. Since necessary use as a source of public water supply is accepted as the most important of all water uses, this is chosen as an example. A source of public water supply should be protected against:

1. Excessive bacterial and viral contamination.
2. Toxic substances.
3. Excessive changes in physical characteristics, such as temperature and color.
4. Substances causing taste and odor.
5. Excessive mineralization.
6. Undue interference with or increased cost of chemical water treatment such as coagulation and chlorination.
7. Undue interference with sedimentation and filtration.
8. Abrupt changes in water quality that disrupt treatment processes.
9. Deterioration of concrete and metal structures and equipment.
10. Nutrients that promote excessive biological growths which cause taste and odor or interfere with water treatment processes.

There are literally hundreds of substances that may cause one or more of the foregoing effects. This fact illustrates the care with which specific objectives must be selected and defined.

The foregoing presupposes sufficient knowledge of the stream problem to permit adequate definition of specific objectives in advance. In actual practice this definition may not be feasible until additional information has been assembled.

PRELIMINARY PLANS

All available information pertinent to the problem should be assembled for review and development of preliminary plans.

A good map of the area, including the stream, is essential. The U. S. Geological Survey has topographic maps covering much of the

United States. If the Corps of Engineers or the Bureau of Reclamation has examined the area they usually have a file of useful maps. State and local highway departments can provide maps showing roads that provide access to the stream.

The Weather Bureau is a source of useful climatological data. These data indicate periods of maximum temperature and minimum rainfall which usually are preferable for stream surveys.

Records of stream flows may be available from the U.S. Geological Survey or from the state agency which cooperates with the Survey. If the necessary stream gaging stations have not previously been established, the Geological Survey usually will provide this service, on a reimbursable basis, through establishment and operation of temporary stations. The Corps of Engineers, the Bureau of Reclamation, and private power companies maintain stream flow records in the vicinities of their operations.

All communities and industries discharging wastes that may contribute to the problem should be located. Census figures for the communities are readily available and state health departments or water pollution control agencies usually can provide information on sewered populations and sewage treatment. Chambers of commerce and state departments that deal with industries maintain lists of manufacturers.

Municipal and industrial water plants may have useful records of water quality. The U.S. Geological Survey has records of mineral content of water in many areas, and the U.S. Public Health Service is initiating a program that will develop records of sanitary water quality at selected points. Several states are initiating similar sanitary water quality programs.

Reports of previous water pollution studies of the stream involved may be available. These should be assembled and reviewed. State health departments or pollution control agencies may have unpublished data that can be made available.

After available information has been reviewed a tentative survey plan should be outlined. This may include:

1. Location of stream gaging stations.
2. Location of sampling stations.
3. Sampling schedule.
4. Field and laboratory determinations.
5. Types and numbers of personnel needed.
6. Means of transporting personnel, equipment and samples.
7. Duration of survey.

From this outline the probable cost of the survey can be estimated. This initial plan should include all factors desirable for the best possible approach to the problem to be solved. Not infrequently budgetary or personnel limitations will require elimination of less essential features of the plan, but cutbacks can be made more intelligently if the initial plan is a comprehensive rather than a partial one.

PRELIMINARY FIELD REVIEW

A thorough review of the problem in the field is an extremely important step in preliminary planning. Local details may vary markedly from mental pictures developed through examination of maps and reading reports. A bridge which appeared ideally suitable as a sampling point, on the map, may have been abandoned or may be approached by a road that is

impassible in wet weather. An industry which appears on the map to be close to one stream may discharge its waste to another, more distant stream.

All water uses should be observed, especially in relation to any effects of pollution. Discussions of effects of pollution with local persons familiar with stream uses frequently bring out revealing information. While the layman may not understand the technical factors involved, and his opinion may be biased, his observations and opinions often include bits of information of significance to the trained pollution investigator.

Sources of waste and points of discharge should be located on a map. A fair approximation of quantity and strength of sewage discharged to the stream may be obtained from figures on the population connected to the system and the type of treatment provided. Quantities and strengths of industrial wastes are more difficult to estimate. If possible, each industrial operation should be reviewed and flow diagrams of processes prepared. These diagrams should include points of water use and of waste discharge, with both qualitative and quantitative information, where available, on the waste streams and their contents. If raw material and production figures can be obtained they should be recorded. Seasonal or other variations should be noted. Industrial waste guides for many industries are available from the Public Health Service and other sources. These usually relate waste volumes and constituents to production units, and can be used to obtain a rough estimate of wastes to be anticipated from an individual plant. Any industrial waste treatment facilities should be noted.

If it appears desirable to sample either sewage or industrial wastes, points at which weirs or other flow measuring devices can be installed and at which samples can be collected should be investigated.

The stream should be observed thoroughly. Small streams may be followed by foot, and larger ones by boat. Points of waste discharge and patterns of mixing and dilution with the stream water should be observed. This information is useful in determining whether a single sample at midstream or at several points for compositing across the stream will be necessary at downstream stations. Waste often hugs the bank from which it is discharged for many miles downstream before it mixes with the entire stream flow.

While investigating the stream, evidences of pollution should be noted. Floating materials, suspended solids, color, and gas bubbles are readily observed. Sludge deposits may be discovered by probing with a stick, or by dropping heavy objects in areas where the water moves slowly. If pollution is severe the odor of hydrogen sulfide may be evident. An experienced biologist can learn much about the condition of the water by observing visible aquatic life. Riffle areas suitable for collection of biological specimens should be located.

Especial attention should be paid to the points on the stream already tentatively selected from maps as sampling stations. Their suitability can now be judged on the basis of the acquired knowledge of the stream. They should be considered, for example, with respect to the type of sampling equipment that can be used. If the stream is shallow a hole for submerging the sampling device must be located or perhaps even excavated. If a bridge is used, the length of rope needed to reach the

water should be determined. If the stream is swift, special weights to submerge the sampler may be necessary. It may be necessary to install steps in the stream bank or to build a plank walkway out over the stream. Unless a bridge is available a method of access to the sampling point must be determined, and possibly prepared by cutting away underbrush, bridging small gullies with planks or making similar improvements. Where the sampler has to carry heavy equipment to the sampling point and return with the added weight of the water, the route should be made as convenient as reasonably possible.

During the trip on the stream times of water travel between pertinent points may be determined, but this procedure is time consuming and probably can best be accomplished as a separate project. In any event, times of water travel for several stream flows, within the range of flows that may be involved, should be determined in advance of the sampling program. The Corps of Engineers has data on cross sections at frequent intervals on many navigable rivers that they have surveyed. If these are available they may be used to calculate average velocities for various flows, from which times of water travel can be obtained. If cross sections are not available from the Corps or elsewhere, they can be determined by a special crew. In shallow streams they can be measured with a stick while wading. In deeper streams it may be necessary to use a boat and weighed cable. A boat equipped with sonar, if available, is particularly useful on large bodies of water. All depth measurements must be integrated with distances and elevations along the stream by methods common to regular mapping surveys. Stream flows during the periods of measuring cross sections must be recorded. Other means of

obtaining stream velocities may be preferable. Floats can be followed downstream and timed. Oranges may be used, since they float almost submerged and tend to roll around or under obstructions, and their color makes them readily visible. Surface floats tend to drift into side eddies and remain there. When this occurs they should be moved back into the main thread of the current. If surface floats are used properly they will indicate about 0.85 of the average stream velocity. Probably the most reliable method of determining times of water travel is to follow some variation in water quality downstream. If an industry closes down temporarily, or discharges a waste that varies widely in composition or strength it may be feasible to follow the resulting change in the stream. If this is not practicable it may be possible to add some material to the stream that may be detected by visual, chemical, conductive, or radiological methods. Use of this type of measurement generally will be restricted to relatively small streams.

Any of the float or direct measurement methods must be conducted at several different stream flows to permit development of a curve relating time of water travel to all stream flows within the range involved.

Time of water travel data will be useful in the final selection of sampling stations and during the sampling program in following downstream and observing any unusual change in water quality, such as that caused by an accidental spill of an industrial waste. Times of water travel are essential to the complete analysis, interpretation, and projection of much of the analytical data. Rates at which reactions occur in streams are extremely important with respect to the effects that wastes exert on downstream water uses.

Preliminary samples should be collected at the tentative sampling stations. Both field and laboratory determinations should be made. The analyses will serve to point up any potential difficulties in analytical procedure that should be resolved before the survey starts. The results obtained will be useful in final selection of sampling stations. They may reveal that some determinations proposed in the initial plan do not yield significant results, and should be abandoned.

If the area of field operation is some distance from the headquarters organization, local sources of ice for preserving samples, gasoline for cars and boats, and emergency supplies and services should be located. Availability of rooming and eating facilities for field personnel may be determined, with especial reference to convenience to the center of field activities. If a field office or laboratory must be established, arrangements should be made for necessary space and facilities. It may be necessary to arrange for renting a boat and hiring an operator or other types of local personnel.

It is not possible to over-emphasize the importance of a careful and thorough preliminary field review of the problem area. One or two men can perform this duty and can prevent much loss in time and money when the much larger field crew arrives on the scene.

FINAL PLANS

With the background information obtained the revision of the preliminary plan to provide a final plan can be undertaken intelligently and with assurance.

The objectives of the survey should be written out in detail as a prelude to crystallizing the means of attaining the objectives. All uses of water and all waste constituents that may interfere with the uses should be considered.

Final selection of sampling stations can be made. Desirable locations will vary with the types of important waste constituents, the nature of the stream, the anticipated stream flow, and the locations of water uses. For example, if oxygen depletion by organic wastes is important, stations generally should be at relatively short intervals below the source or sources of waste. Oxygen recovery from moderate pollution should be fairly well advanced in most streams within four to seven days' time of water travel downstream. In the upper half of this section stations might be one-half to one day apart, and in the lower half one to two days apart. One station should be as near as is practical to the point of maximum oxygen depletion. In terms of distance the intervals between stations will vary with the type of stream. A shallow stream with high velocity may recover from oxygen depletion in a relatively short time, but may travel relatively far in so doing. A deep, slow moving stream requires a much longer time to recover, but may not travel so far in the time required. Total distances that must be covered below a major source of waste generally will fall in the range of five to twenty miles. The data obtained in the preliminary field review will be useful in determining the proper spacing of stations.

On the other hand, the effects of bacterial contamination and some of the more persistent types of wastes may carry much farther downstream. Examples of the latter are phenol, which causes taste and odor in water

supplies, and ammonia, which may interfere with chlorination. In such cases the stations can be farther apart and the total distances covered must be greater.

Sampling stations should be located at points where water use may be affected. All important tributary streams should be sampled near their mouths. A station immediately above the point of each waste discharge is necessary to provide a base of reference.

If a waste fails to mix rapidly with the receiving stream it may be necessary to sample downstream stations at several points across the stream. A common practice in such cases is to sample at quarter points. Field determinations are made on water from each point, but composites of equal portions from the several points may be made for most laboratory examinations. Compositing of samples for bacteriological examination is not recommended, however.

If it is not feasible to obtain representative samples immediately below a source of waste it may be desirable to estimate the immediate effects of the waste on the stream by combining results on the stream above the source of waste with results of gaging, sampling, and analyzing the waste itself. It usually is desirable to establish the characteristics of all major sources of wastes through measurement, sampling, and analysis. If the wastes are fairly consistent from day to day their examination may be scheduled during a different period than that of the stream sampling program. If the examination can be made in advance of stream sampling the data obtained will be useful in planning the stream survey.

After the stations have been selected they should be identified, on the ground, by code letters or numbers marked on nearby fixed objects.

The frequency and duration desirable for sampling sources of waste vary with the type of source. Sewage varies rather widely in both strength and volume during each day. It is common practice to sample sewage each hour and combine hourly portions in proportion to flow to obtain a 24 hour composite. If a reliable estimate of sewered population is available two or three 24 hour composites may be adequate to confirm the population estimate. When the latter is not available, or if significant industrial waste is discharged to the system, it may be desirable to sample the sewage each day for at least a week.

The characteristics of wastes from the more common industries have been determined by examination of wastes from a number of plants in each category. Publications containing these data provide a general idea of the wastes that may be expected from a particular industry. However, wastes from different plants within the same industry vary so widely that reliable evaluation of wastes from an individual plant must be based on examination of the particular wastes.

Some industries operate throughout the day and from day to day with only minor variations in waste volume and concentration. Such wastes may be composited in equal hourly portions for two to three periods of four to eight hours each. Other industries operate on cycles that produce wide variations in both volume and concentration of the wastes. Such wastes should be sampled for several complete operating cycles, with sample portions composited in proportion to flow at times of collection for each cycle. Preliminary observations of waste flow patterns are necessary to determine the volumes of sample portions necessary throughout the range of flow to assure the needed sample volume on completion of the composite.

Sample portions should be collected at 15 to 30-minute intervals for wastes, that vary widely. Still other industries produce wastes that vary without any particular pattern. These wastes should be composited at short time intervals in proportion to flow for either the full operating day or for 24 hours if the process is continuous.

In cases where there is a marked peak in waste production it may be desirable to composite the waste discharged during the peak separately from the full day's composite.

Stream samples are collected once daily or two to three times per week for most surveys. Generally eight to twelve complete sets of samples will provide a basis for reasonable evaluation of the pollution problem if stream flows and waste discharges do not vary too widely during the survey period. Sampling trips should be varied to the maximum practical extent to avoid sampling the same station at the same time each day. One or more sampling trips at night may be desirable. This is especially important if the stream contains abundant algae that add significantly to the dissolved oxygen of the water through photosynthesis. Polluted streams have been found in which dissolved oxygen was at acceptable levels during the day but dropped to low concentrations or even to zero during the night.

If there are wide daily variations in either waste discharge or stream flow, daily grab samples on the stream may not yield representative results. Flows of uncontrolled streams normally do not vary suddenly except for rises following rainfall. Impounded streams, especially those controlled for power production, vary not only widely from day to night but also suddenly from one hour to another. In such situations it may be necessary to sample each stream station four to six times during a

24 hour period. To avoid an excessive load on the laboratory the samples for each station may be made into a composite. If flow variations are extreme it may be necessary to proportion each sample to flow at the time of collection.

An alternate method in dealing with widely varying conditions is to select an identifyable slug of water, follow it downstream, and sample it as it passes the sampling stations. Means of identification are similar to those used for determining times of water travel. This method probably yields the best results achievable, but has the disadvantage of requiring a large field crew. It defines rather precisely the conditions existing during the sampling period but, unless repeated several times, fails to indicate the range of variations that results from the many variables to which the waste in the stream is subjected.

The field and laboratory determinations to be made should be chosen with care. Emphasis should be placed on inclusion of all determinations necessary to assure attainment of the survey objectives. Equal emphasis should be placed on exclusion of determinations that would be interesting but would not contribute to the solution of the problem. Many reports have long tables of results of determinations, obtained at the expense of much time and effort, which receive scant comment in the text.

Minimum basic determinations when sewage only is involved should include those for temperature, coliform organisms, dissolved oxygen, biochemical oxygen demand, and attached biological organisms. Turbidity, color, pH and alkalinity are other common determinations, principally to establish whether or not the natural stream water is reasonably normal. Other determinations for special purposes may include carbon dioxide,

hydrogen sulfide, the various forms of nitrogen compounds, phosphates, iron, manganese, and plankton. Intelligent selection of the determinations to be made depends on careful consideration of the natural stream water quality, the sewage, and the water uses involved.

When organic industrial wastes cause the pollution the basic determinations are the same as for sewage pollution with the exception of those for coliform organisms. Additional determinations that may be needed are dependent upon the raw materials used and the intermediate and finished materials produced in manufacturing. Practically no process operates without some loss of materials. Obviously it would be futile to attempt here to suggest the special determinations needed to cover the field of possible organic industrial pollutants. The fish bioassay determination, which establishes the median tolerance level of toxic materials to fish, frequently is useful in surveys dealing with industrial wastes.

Where inorganic industrial wastes cause pollution the choice of determinations is simplified. Biochemical oxygen demand is not a part of the problem, and dissolved oxygen depletion only rarely is a factor. Even a complete mineral analysis of water usually involves only 15 to 20 constituents. In most cases only a limited number of the inorganic chemicals used in plant processes will be of concern.

When decisions have been reached on the number of sampling stations and the essential laboratory determinations, the capacity of the laboratory to process the samples must be discussed with laboratory personnel. Failure to realize laboratory limitations is a factor common to many pollution surveys. The result is an overloaded laboratory and an

overworked staff. This situation can lead to irritation and dissension, and to the even more serious matter of poor analytical results. Only when a realistic laboratory load has been established can a realistic sampling schedule and duration of survey be adopted.

No attempt will be made here to suggest laboratory methods to be used. "Standard Methods for The Examination of Water, Sewage and Industrial Wastes," 10th edition, 1955, is the official reference for stream pollution work. It includes methods for the determinations that will be found necessary for most pollution surveys.

The laboratory should be allowed a reasonable length of time to prepare necessary solutions and assemble equipment and supplies.

A check list of field equipment and supplies should be prepared and followed in assembling the required materials and ascertaining their working order. Procurement of a minor item, or repair of a piece of equipment that may take only a few minutes at the headquarters location often can prevent hours of lost time for the crew in the field.

Personnel requirements become obvious when the planning has reached this stage. They commonly include:

Sanitary Engineer (usually in charge of survey)
Chemist
Biologist
Bacteriologist (only when sewage is involved)
Sampling Aide
Handyman

All personnel should be assembled for briefing on the survey. A description of the situation and a clear statement of the survey

objectives will stimulate interest that will lead to better performance of duties. It is desirable, if feasible, to take the entire staff on a tour of pertinent points in the field. The subsequent work can be performed more intelligently if all have a clear understanding and mental picture of the situation.

A dry run of sample collection and field determinations should be made. This run may be combined with the staff tour. This will provide information on the time required for a sampling trip. It will permit checks on the working order of field equipment, applicability of the equipment to field conditions, and on performance of the field crew.

Definite assignments of responsibilities for various phases of the project should be made by the supervisor and should be understood by the individuals involved.

CONDUCTING THE SURVEY

If the planning has been thorough and capable personnel are provided, the actual survey will operate almost automatically. Poor advance planning can cause much lost time and gaps in sampling routine, and in extreme cases can lead to poor end results or even to failure of the survey.

Means of communication among all personnel should be established. Much time can be saved in making program adjustments and in overcoming operating irregularities if regular contact among personnel is maintained.

All records should be kept in bound books. Many individuals are prone to jot miscellaneous data on slips of paper, which are easily lost,

or to assume that they will be able to remember pertinent items.

Both field and laboratory personnel should be alert to note and record abnormal circumstances or results that appear to be out of line. Such observations often provide valuable clues in the subsequent analysis and interpretation of data.

Data should be computed to final form and reviewed daily. Such review will reveal irregularities that should be checked, and will indicate the progress of the survey. It may well lead to revisions in the program that will improve the end results or to the omission of nonproductive features that will save time. Although the planned program should not be changed without valid reasons, it should not be followed blindly if convincing reasons for change emerge as the data accumulate.

All personnel, from supervisor to dish washer, should be imbued with the importance of their respective duties. Clean glassware is essential to accurate laboratory determinations and a careless dish washer can defeat the most painstaking efforts of the laboratory analysts. The samplers must peform precision work under conditions that frequently are difficult. A few drops of strong field reagents introduced by error into the wrong bottles can cause mysterious errors in the final results. An error in labelling can invalidate an entire sample. The samplers see the stream more than any other members of the crew and, if alert, can record special observations that will be invaluable in the analysis and interpretation of data. The necessity for accuracy usually is so ingrained in laboratory personnel that it scarcely needs repeating here. And finally, the supervisor generally finds that he needs to be two

or more persons to allow him to be everywhere at once.

PREPARATION OF REPORT

It is not the purpose of this discussion to go into the techniques of data analysis and interpretation. The entire time allotted to this conference would be inadequate for full development of this important phase of a stream pollution survey. Time permits only a few general comments on report preparation.

All computations and transfers of data should be checked. Even the most careful individual inevitably makes errors in manipulation of data.

Every report should include a map of the stream and adjacent area, showing locations of pertinent items. Pages of description can not convey the mental picture that can be gained from a single map. Liberal use of charts and graphs for presentation of data is desirable for the same reason.

The writer should consider the probable future use of the report as well as its immediate purpose. All sampling and gaging points, for example, should be identified so that they can be located without question if a subsequent survey should be made. Analytical and other methods should be specified if a choice of methods is available. All basic data should be incorporated in the report, usually in an appendix. Methods of interpreting data should be described. It should be possible for an individual not connected with the survey to use the report even many years later as a reliable guide in dealing with subsequent problems.

The report should contain a reasonable amount of necessary background description. On the other hand, inclusion of interesting but irrelevant material should be avoided. Some reports contain so much extraneous material that the reader loses interest before reaching the pertinent portions of the text.

Decimal point accuracy must not be expected of stream surveys. There is a tendency, perhaps, to discredit the results of a survey if all data do not fit into smooth curves, or if some computations yield unanticipated and apparently inexplicable results. It is possible to make basic measurements such as stream flow and chemical content with considerable precision. It is not possible to pour a living, ever-changing river, subject to the many variables mentioned in the opening paragraph, into a laboratory bottle for submission to the analyst's exact measurements.

The successful execution of a stream pollution survey requires a blending of both art and science. Nevertheless, the experienced pollution investigator can resolve even the most challenging stream pollution problem through application of energy, ingenuity, and sound judgment.